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WhiteSpace Alliance™ – www.WhiteSpaceAlliance.org

• WhiteSpace Alliance is a technology neutral organization – It promotes the use of unused and under-utilized spectrum

• WSA engages in market awareness and advocacy related activities

• The Alliance creates and simplifies standards

• WSA will conduct programs for inter-operability between products

• WSA plans to adopt IEEE, IETF and 3GPP Standards for use in the WhiteSpaces.
WhiteSpace Alliance is a Global Organization

TVWS Workshop (India) With TV Broadcasters

Various Industry Events
WhiteSpace Alliance Industry Activities
IEEE Standards Association Hierarchy

IEEE

IEEE Standards Association (IEEE-SA)

Standards Board

Board of Governors

IEEE 802 Sponsor Executive Committee

Review Committee (RevCom)

New Stds. Committee (NesCom)

Patent Committee (PatCom)

802.11 WLAN
Wi-Fi™

802.15 WPAN
ZigBee™

802.22 WRAN
Wi-FAR™

• IEEE is world’s largest professional organization with a mission of Advancing Technology for the Humanity.

• IEEE SA has more than 350 standards working groups
Technologies and Standards in Television White Spaces

IEEE 802.15.4m (ZigBee)
IEEE 802.11AF (Wi-Fi)
IEEE 802.16h Applicable to TVWS
IEEE 802.22 (Wi-FAR)

3GPP – LTE + Other Proprietary
P1900 (DySPAN-SC)
IEEE 802.22 (Wi-FAR)

More than $125M invested in creating TV WhiteSpace Standards

WRAN
WMAN
WLAN
WPAN

IETF - PAWS (Database)
WhiteSpace Enabled Rural Broadband to Cognitive M2M © WhiteSpace Alliance
• **Developed Countries**: More than 500 MHz of spectrum will be required before 2020 to support emerging wireless broadband services and applications.

• **Developing Countries**: Cost effective broadband access is still a challenge in rural areas and developing countries.

• **Spectrum sharing** can create tomorrow’s spectrum super-highways. It supports licensed, license-exempt and hierarchical access business models

• **Technologies** such as Cognitive Radios, and Database Enabled spectrum access exists

• **Regulations** to support spectrum sharing need to be developed

*These are authors’ personal view-points and do not represent the viewpoints of any other organization*
Why Share the Spectrum?

- United States Presidential Memorandum of June 2010 requires 500 MHz of spectrum to be made available for commercial use within 10 years
- Huge WW Mobile Device Growth Opportunity (2020)
  - $4.5T Global Value
  - M2M Wave next
  - 50B devices
  - Zetta-bytes of Data
- Enhanced Mobile Devices are Already Leading to a US Bandwidth Deficit
  - Data more than doubled 4 years in a row
  - Smartphones generate 24X data of basic-feature cell phones
  - Tablets create 5X more traffic than smartphones
- Federal Agencies also need more Spectrum
  - DOD unmanned aerial systems increased 45X in 8 years

PCAST: United States President’s Council of Advisors on Science and Technology

Courtesy: Mark Gorenberg, Hummer Winbald Venture Partners
Average Spectrum Occupancy in Various Bands

Estimated Spectrum Occupancy by Band up until October 2010. Average overall occupancy is 14% for 30-3000 MHz Band

PLM, amateur (30-54 MHz)
TV 2-6 (54-87 MHz)
FM (87-108 MHz)
Amateur (108-174 MHz)
TV, maritime (174-225 MHz)
Fixed, mobile, others (225-406 MHz)
LMR, others (406-475 MHz)
TV (475-698 MHz)
700 MHz auction (698-798 MHz)
SMR (798-840 MHz)
Cellular (840-902 MHz)
Unlicensed (902-928 MHz)
Paging Systems (900-1000 MHz)
IFF TACAN GPS etc (1000-1240 MHz)
Amateur, radar, military, GPS (1240-1710 MHz)
PCS cellular, Asyn Iso (1710-2010 MHz)
TV aux, Common carriers, Private (2.01-2.2 GHz)
Space, Operations, Amateur (2.2-2.4 GHz)
ISM (2.4-2.5 GHz)
WiMAX, ITFS, MMDS (2.5-2.7 GHz)
Surveillance Radar, others (2.7-3.0 GHz)

Min
Avg
Max

Courtesy: Peter Flynn, Texas Instruments, Understanding Kaleidoscope of Unlicensed Spectrum originally derived from D. Roberson IIT Research
Why share spectrum: PCAST recommendations

- Clearing and Reallocation of Federal Spectrum is Not Sustainable.
  - Recent NTIA Study - Clearing of just one 95 MHz band will take 10 years, cost $18 billion, and caused significant disruption.
  - Net revenue from last successful auction of 45 MHz realized a net income of just a few hundred million a year for the government. ($5.3 billion total)
- More Efficient and Immediate Use of Federal Spectrum will be Obtained through Sharing

Courtesy: Mark Gorenberg, Hummer Winbald Venture Partners
PCAST recommends the President issue a new memorandum that:
• states the policy of the U.S. government is to share underutilized Federal spectrum; and
• identifies immediately 1,000 MHz of Federal spectrum for sharing with the private sector; and

The New Spectrum Superhighway:
• Divides spectrum into substantial blocks with common characteristics
• Makes sharing by Federal users with commercial users the norm
• Measures spectrum effectiveness using a new metrics
• Increases capacity and spectrum re-use by 1,000’s of times.
**Co-existence Enablers**: In general, these techniques are widely accepted to enable spectrum sharing –

WhiteSpace Alliance Supports All these Mechanisms

- Cognitive Radio and Advanced Transmitter / Receiver Technologies
- Spectrally Efficient Waveforms
- Spectrum Database
- Spectrum sensing
- Beaconing
WhiteSpace Applications

Intelligent Transportation System

Internet of Things (IoT)

Spectrum Occupancy Sensing (SOS) - IoT

Smart cities

Smart Home
Providing cost-effective RURAL broadband is a significant opportunity

- Today, 73% of the people in the world (5.1 Billion people) do not have access to internet. More than half the population in the world live in rural areas with hardly any access to broadband.

- It is expensive to lay fiber / cable in rural and remote areas with low population density. Wireless is the only solution. Backhaul / backbone internet access for rural areas is very expensive (50% of the cost)

- Traditional wireless carriers have focused on urban areas with high populations density (faster Return on Investment) using licensed spectrum

- This has created a DIGITAL DIVIDE / OPPORTUNITY
Relative Cost and Complexity of Various Technologies for Rural and Regional Area Broadband Service

Population density (per km²)
Relative Complexity and Cost (%)
Suburban
Urban
Dense urban
Rural
Sparsely populated

Optical fiber
Cable modem
ADSL
Mobile broadband
Satellite

Fixed broadband at lower frequency

Population per density bin (Million)

Population density (per km²)

 NASCAR 2007 (scale 10 to 100)
Canada
USA

FCC Definition of ‘Rural’

4 W Base Station
100 W Base Station
4 W User terminal

ADSL, Cable, ISM and UNII Wireless and Optical Fiber
Satellite
WRAN

Courtesy: Gerald Chouinard: gerald.chouinard@crc.ca
Spectrum: Optimum frequency range for large area Non-Line-of-sight Broadband Access

Relative Complexity and Cost (%)

Frequency (GHz)

Antenna aperture

Ground wave reach

Ionospheric reflection

Industrial noise

% bandwidth

Foliage absorption

Doppler spread

Phase noise

Outdoor/indoor attenuation

Filter selectivity

Rain fade

Cosmic noise

Noise Figure

Courtesy: Gerald Chouinard: gerald.chouinard@crc.ca
Southern Ontario Canada

Many Channels Available in Rural Areas

Rural Areas

Urban Areas

TV Channel Availability for Broadband

Source: Gerald Chouinard, CRC and Industry Canada

- VHF / UHF bands traditionally have highly favorable propagation characteristics. Penetrating through foliage and structures, they reach far and wide.

- **WhiteSpaces** offer ten times the coverage and three times the capacity of the Wi-Fi™ spectrum
WhiteSpace Applications

BEFORE

Now

Rural Broadband and Backhaul
TV WhiteSpace Availability in the United States

Peter Flynn, Texas Instruments, White Space - Potentials and Realities
• There is a dire need for cost-effective backhaul and middle mile solutions for broadband access in both developed and developing countries
• Licensed carriers do not want to use their precious spectrum for backhaul. They would rather offload as much as possible to some other spectrum.
WhiteSpace Applications

Triple play

Cellular offload

Critical infrastructure monitoring

Border protection

Emergency broadband infrastructure

Environment monitoring
WhiteSpace Applications

Archipelago and marine broadband service. Servicing oil rigs

- TVDB = (TV Database)
- LC- CPE = Low Complexity CPE

Remote medical service

C. W. Pyo, Use Cases for IEEE 802.22 (Wi-FAR(TM)) Smart Grid and Critical Infrastructure Monitoring
Cognitive machine to machine (CM2M)

50 Billion machine to machine devices will be deployed by 2020

By 2020 Wireless Technologies are likely to contribute $4.5 Trillion to global economy through organic growth and new disruptive M2M technologies
WhiteSpace Applications

Peter Flynn, Building a Wireless Infrastructure: the Critical Role of Backhaul, Texas Instruments

- All that matters is seamless connectivity and user experience.
- Licensed, license-exempt and shared spectrum is needed for that
TVWS Regulations Around the World

**Canada Regulations on-going** – 80 MHz (Ch. 21-51) have already been open for light-licensing for remote rural broadband access since June 2009. TVWS rules are being harmonized with the rules in the US.

**USA Regulations completed** – Total 288 MHz freed up (Sept 2010) for license-exempt operation. Geolocation database, sensing optional – *Incentive auctions could change this.*

**UK Initial Rules Released (July 5th, 2012)** – License-exempt database driven approach, different classes of devices, sensing optional.

**EU (CEPT) Discussions on-going** – license-exempt, collaborative sensing, database approaches considered. Variable transmit power based on device capabilities, microphone protection beacon.

**Brazil** – DTV transition on-going. Realizes the importance of broadband for rural (e.g. Res. 558, Operation in 450 – 470 MHz)

**ITU** – Several study groups are discussing cognitive radio based operation. TVWS being discussed in WP1B, WP5A as well as WP6A.

**Egypt** – interested and participating in IEEE 802

**Japan (MIC)** Discussions on-going Final rules before 2015. 10 WS projects under way – WS Test Area to be allocated.

**Singapore Testing devices on-going (IDA)** – Final rules before 2015. 12 channels for testing. May allow bonding of up to 8 channels. Sensing, database required.

**India Discussions on-going** – 368 – 380 MHz for rural. 470 MHz – 585 MHz for WhiteSpaces. Further discussions in 2015 time-frame.
TV White Space Trials and Deployments

Currently operational TVWS trial deployments

Rural Broadband: Nation’s first TVWS network – Claudeville, VA

“Smart Grid” Network Deployment – Plumas-Sierra Rural Electric Co-Op, CA

“Smart City” Network Deployment – Wilmington, NC
Partnership with city and Public Safety

Telemedicine Applications – hospital campus – Logan, OH

Tribal and Public Safety Remote Area Deployment – Yurok Reservation, Arcata, CA

Super WiFi Network Deployment – Cambridge, England – and 2 Spectrum Bridge networks in Finland
In UK, 1-year trial: package of use cases by consortium 14 companies (Microsoft, BT, BBC, Neul, Nokia, Adaptrum)

Courtesy: Michael Calabrese, NTIA ISART Symposium
Upcoming Pilot Programs

Brazil Pilot Program
Santa Rita do Sapucaí

India Pilot Program
Mumbai and Pune
TVWS Database Service Providers

- Airity
- Comsearch
- Google
- key bridge
- LS telcom
- Neustar
- Microsoft
- Spectrum Bridge
- Iconectiv

experience performance results
IEEE 802.22 WG on Cognitive Radio Based Spectrum Sharing and Wireless Regional Area Networks

IEEE 802.22 WG is the recipient of the IEEE SA Emerging Technology Award

IEEE 802.22 Standard – Wireless Regional Area Networks: Cognitive Radio based Access in TVWS

IEEE 802.22 Standard for Operation in Bands that Allow Spectrum Sharing

802.22.1 – Std for Enhanced Interference Protection using beaconing

802.22.2 – Std for Recommended Practice for Deployment of 802.22 Systems

802.22a – Enhanced Management Information Base and Management Plane Procedures

802.22b Enhancement for Broadband Services and Monitoring Applications

NEW!! Spectrum Occupancy Sensing (SOS)

Apurva N. Mody, Chairman, IEEE 802.22 Working, apurva.mody@ieee.org,
Chang-woo Pyo, Vice Chair, IEEE 802.22 WG, www.ieee802.org/22
IEEE 802.22 (Wi-FAR™) Provides Three Mechanisms for Incumbent Protection

- Sensing
- Database Access
- Specially Designed Beacon

Security Sub-layers are introduced to protect non-cognitive as well as cognitive functions

Cognitive Plane is used to control the Cognitive Radio Operation. Security Sublayer 2 is introduced for protection against Cognitive Threats

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TV Channel Modeling – Only IEEE 802.22 (Wi-FAR™ supports large multi-path delay absorption

- Long distance communication in the VHF/ UHF Band needs to deal with severe multipath and delay spread conditions
- Frequency selective with large excessive delay
  - Excessive delay (measurements in US, Germany, France*)
    - Longest delay: >60 μsec
    - 85% test location with delay spread ~35 μsec
  - Low frequency (54~862 MHz)
  - Long range (up to 100 km)
  - Slow fading
    - Small Doppler spread
    - (up to a few Hz)

* WRAN Channel Modeling, IEEE802.22-05/0055r7, Aug 05
Information provided by TV Broadcasters
IEEE 802.22 (Wi-FAR™) – Frame Structure

- Time Division Duplex (TDD) frame structure Super-frame: 160 ms, Frame: 10 ms
- OFDM/ OFDMA Transport
- QPSK up to 64 QAM modulation supported
- Convolutional codes and other advanced codes supported
- Throughput: 22-29 Mbps per TV channel WITH NO MIMO. MIMO and channel bonding increase the throughput
- Spectral Efficiency: 0.624 – 3.12 bits / sec / Hz
- Distance: 10 km minimum. Upto 30 km and even 100 kms
- MAC supports Cognitive Radio features
- Self-coexistence Window (SCW): BS commands subscribers to send out CBPs for 802.22
The allocation of burst could be based on distance of CPE from BS in order to compensate the propagation delay under overlapping cells.

IEEE 802.22 systems are designed to accommodate propagation delays and channel delay spreads of up to 100 km.
WhiteSpace Alliance Technologies – Databases and Radios
**WhiteSpace Technologies**

**Databases and Radios**

**NICT IEEE 802.22 Prototype**

**Nutaq 0.3 GHz to 3.8 GHz SDR Platform**

**AmeriSys 802.22 SDR**

**TI / Azcom 802.22 and LTE Solution**
Conclusions

• Spectrum sharing can benefit *developed and developing countries*

• Spectrum sharing can create *tomorrow’s spectrum super-highways*. It supports licensed, license-exempt and hierarchical access business models

• There is a dire need to resolve cost-effective backhaul and middle mile problem. TV Band WhiteSpaces along with the right technologies offers a way to create digital divide into a digital opportunity.

• *Regulations* to support spectrum sharing are evolving.

• *Products and Solutions based on Technologies and Standards* for spectrum Sharing and Database enabled Spectrum Access are emerging
  
  • Emerging Technology Award Winning IEEE 802.22 (Wi-FAR™) is specifically designed for rural, regional areas and developing countries to provide broadband access aimed at removing the digital divide. Devices are emerging
  
  • IEEE 802.11af (Wi-Fi™) Standard for TVWS
  
  • IETF Protocol to Access White Spaces (PAWS) Standard for Database access
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